CHRONOLOGY

1831. Capt. William Reid began hurricane studies on the island of Barbados.
1838. Reid published his laws of storms.
1847. Reid established display of signals at approach of storms.
1870. Father Benito Viñes became director of Belen College and inaugurated a hurricane-forecasting service, for Cuba.
1870. February 9: United States Congress made appropriations for a national meteorological service.
1873. August 6: Daily reports from Cuba and other West Indies islands first received.
1875. September 11: Father Viñes issued first hurricane warning.
1876. Set-back in development of hurricane-warning service due to discontinuance of reports from West Indies.
1881. West Indian reports again suspended; legality of expenditures outside of United States questioned.
1889. January 1: Meteorological service for Cuba organized under direction of Naval Observatory of Cuba.
1898. First reorganization of hurricane-warning service to protect American fleet during Spanish-American War; bill for providing funds submitted to Congress June 16; approved July 7.
1898. July 25: First observing station opened at Kingston, Jamaica, which was made headquarters of hurricane-warning service.
1899. February 1: Headquarters of forecasting service transferred to Habana.
1902. Forecasting service for hurricanes transferred from Habana.
1902. National Meteorological Service of Cuba established.
1919. June 1: Hurricane-warning center for Puerto Rico established at San Juan.
1935. July 1: Second reorganization of hurricane-warning service; service transferred from Washington to centers at Jacksonville and New Orleans.

EFFECT OF THE ATLANTIC OCEAN ON TEMPERATURES IN EASTERN UNITED STATES AS SHOWN BY TEMPERATURE-WIND ROSES [1]

By KATHARINE B. CLARKE

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In the preparation of a thesis concerned with some effects of the Atlantic Ocean upon the climate of eastern United States, a study was made of the effectiveness of the ocean in moderating temperatures at various stations. The decrease in temperature ranges along the Atlantic coast is obvious from maps of the average daily range of temperature (figs. 82, 83, and 84, p. 25, *Atlas of American Agriculture*, Pt. II, Climate, Sec. B, Temperature, Sunshine, and Winds, United States Department of Agriculture, Washington, D. C., 1928); there is a very much smaller daily range along the immediate seashore than inland. The Brownsville region, southern tip of Florida, Cape Hatteras and Cape Cod have in spring, summer, and fall the small daily range of 9° to 12° F. A comparison of the highest and the lowest recorded temperatures (fig. 3, p. 7, and fig. 6, p. 8, *Atlas of American Agriculture, loc. cit.*) shows a pronounced moderating effect of the Atlantic Ocean along the coast, but indicates that this does not extend westward beyond the Appalachian Mountains.

To show, by some quantitative and graphical means, the influence of winds from the direction of the Atlantic Ocean upon the temperatures of coastal and inland stations, temperature-wind roses were constructed: Data used for these roses were the 8 a. m. readings of temperature and wind-direction published on the Washington daily weather maps. Seventeen stations in eastern United States were chosen, and data for 20 years (1906–25) for the months of January and July were compiled and averaged. For each station the following data were obtained: (1) Average 8 a. m. temperature; (2) frequency of winds from the cardinal and semicardinal points; (3) average temperatures with winds from each direction; (4) the departure, from the 8 a. m. average temperature, of these average temperatures for each wind-direction.

From this information the roses were constructed, as illustrated by figure 1, the January and July roses for Boston: The center part is a simple frequency wind rose. On the 620 January days, Boston had a northwest wind 149 times and a southeast wind 23 times. At a convenient distance from the center of the rose (the same distance for all directions and for all roses), a point was chosen as a zero from which to plot temperature departures; minus departures were represented inside the zero point, and plus departures outside. A polygon, which is a perfect octagon, connects the zero points and represents the simple average 8 a. m. temperatures for the 620 days. A heavy line connects the points that represent the departures; it forms the temperature-wind rose, a distorted polygon. The amount and kind of distortion represents the effect upon temperature of winds from the different directions; on the Boston January rose, for example, the mean departure with a northwesterly wind is minus 7.7°, and with a southeasterly wind, plus 7.5°.

Unfortunately it is almost impossible to make a correction for the different latitudes from which the winds come; southerly winds usually bring warmer air, and northerly winds colder air. The greatest interest is in winds from easterly directions, as the purpose of the

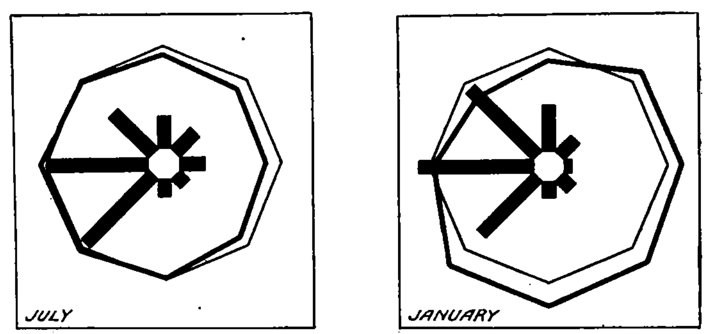

FIGURE 1.

roses is to measure, if possible, marine influence. Local conditions of topography will affect almost every station; Albany, for example, has a very decided minus departure in winter with southeasterly and easterly winds as well as with northeasterly winds, since easterly winds bring colder air from the nearby highlands.

These temperature-wind roses were placed on a map of the eastern United States in their respective positions. Figure 2 shows the roses for January so placed; for purposes of better reproduction, the zero polygons have been changed to broken lines. The distortion of the solid-line polygons indicates that departures from the average are greatest along the New England coast. The roses very clearly show the plus departures with easterly, southeasterly, and even northeasterly winds. This plus departure with an easterly wind in January does not appear at

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inland stations. It is interesting to note the changing shape of the January roses on a line from Cape Hatteras through Charlotte, Chattanooga, and Memphis to Okalhoma City. At Cape Hatteras the polygon is considerably distorted to the south and east, indicating temperatures appreciably above average with southerly and easterly winds. At Memphis there is a pronounced southward and southwestward extension of the polygon, indicating highest temperatures with winds from those directions. A comparison of the lake stations, Buffalo and Chicago, with the Atlantic coastal stations shows that winds from off the Great Lakes bring departures somewhat like those with winds from the Atlantic Ocean.

Figure 3 gives the July temperature-wind roses for all the stations. The solid-line polygons indicate, by their slight distortion, little departure from the average temperature at any wind direction. Greatest distortion occurs along the New England coast. The negative departures when east winds blow is 4°.1 at Eastport, 2°.4 at Portland, 5°.6 at Boston, 1°.6 at Nantucket, 0°.7 at Atlantic City, and 0°.9 at Cape Hatteras. Departures are greatest along the coasts of New England because of the greater contrast between sea and land temperatures, due in turn chiefly to the much cooler sea.

By averaging the departures of southeast, east, and northeast winds (calling this average the "easterly wind temperature"), and taking the difference between this and the average departure of southwest, west, and northwest winds (calling this the "westerly wind temperature"), a numerical measure of the comparative temperatures of easterly versus westerly winds, or, on the Atlantic seaboard, marine versus continental winds, may be obtained. Likewise, by averaging the departures that accompanied the winds from the three northerly directions ("northerly wind temperature"), and subtracting this from the average for the winds of the three southerly directions ("southerly wind temperature"), a numerical measure of temperature with winds from southerly latitudes versus those from northerly latitudes may be obtained. A comparison of the difference between temperatures of easterly versus westerly winds with those of northerly versus southerly winds may be stated in the form of a simple ratio; the numerator has been chosen to represent the difference between easterly and westerly wind temperatures, and the denominator the difference between southerly and northerly wind temperatures.

These computations have been made for each station for January and July and appear in table I. From this table it is evident that during January, at all coastal stations except Atlantic City and Philadelphia, easterly winds are warmer than westerly; but no station away from the immediate coast except Chicago, which has a large body of water to the east, has higher temperatures with easterly than with westerly winds. At every station southerly winds in January bring higher temperatures than northerly winds.

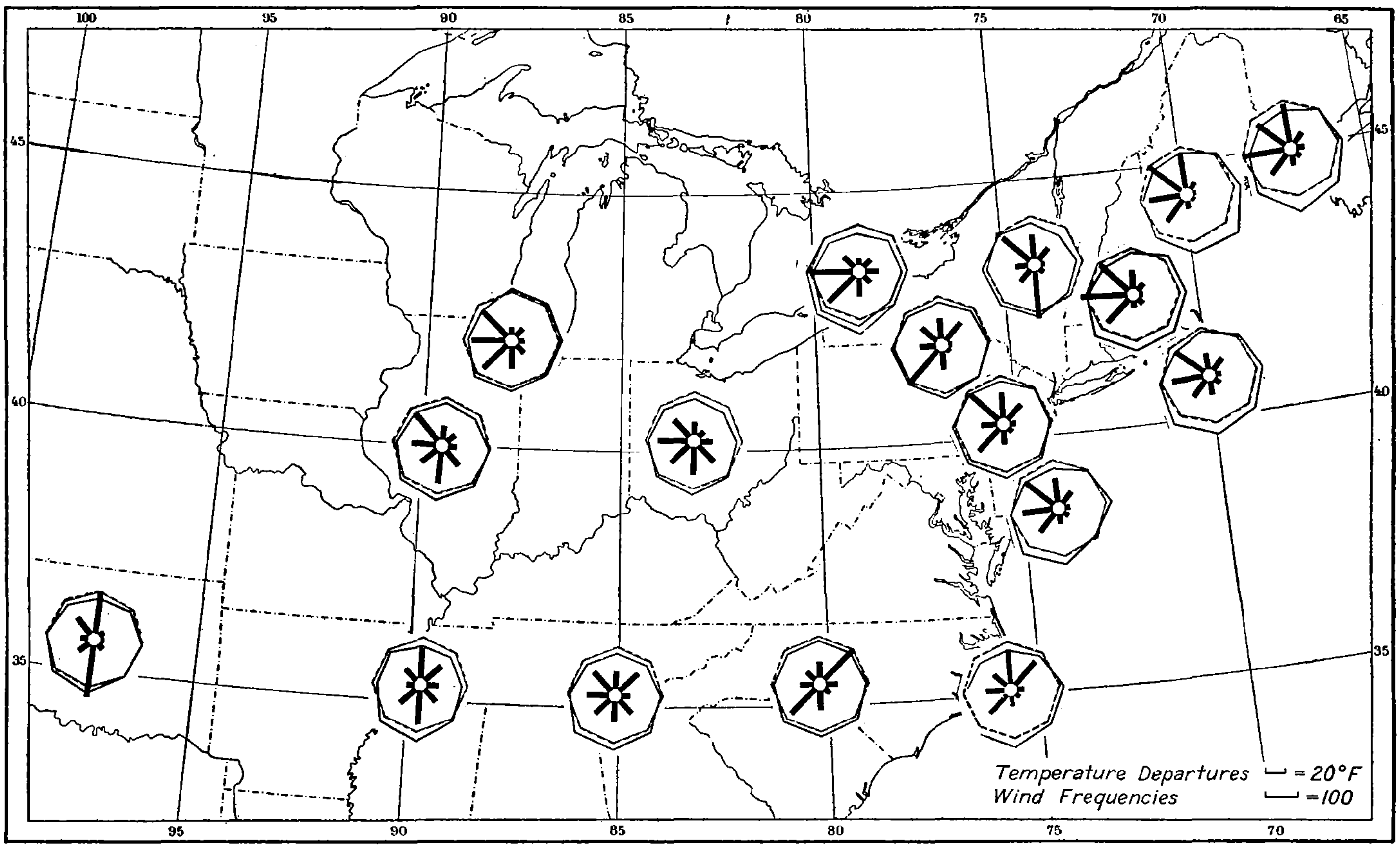

FIGURE 2.

It is somewhat surprising to find that at Boston in January the difference between easterly and westerly wind temperatures is about three-fifths as great as that between northerly and southerly wind temperatures. In other words, easterly winds are no less than three-fifths as effective as southerly winds in bringing higher temperatures. This fraction would be increased if a correction were made for the fact that all easterly winds are not purely marine and all westerly are not purely land winds. If the coast extended indefinitely in a north-south direction, all westerly winds would be from the land, and all easterly winds from the sea; however, in the case of Boston, for example, northeasterly winds may blow over some land surface (Maine), and south-westerly winds may have passed over some water surface (south of New England). Northeasterly winds at Boston, therefore, are not strictly speaking winds from the sea, and are presumably cooler in winter and warmer in summer than they would be if they did not blow over land as well as water before reaching Boston. Likewise, southwest winds at Boston are not strictly land winds, and their passage over water before reaching Boston would tend to make them cooler in summer and warmer in winter than they would be if they had come from a land surface only.

At Portland the ratio for January amounts to five-sevenths. This indicates that the effect of easterly winds in raising the temperature is almost as great as that of southerly winds, even though both come largely off the sea. As previously mentioned, this effect of on-shore winds decreases southward, because of the decreasing differences between air- and sea-temperatures, until at Cape Hatteras the ratio is only one-seventh. However, since Cape Hatteras is surrounded by water, there is local warming of the continental winds, which decreases the difference between temperatures with easterly and westerly winds.

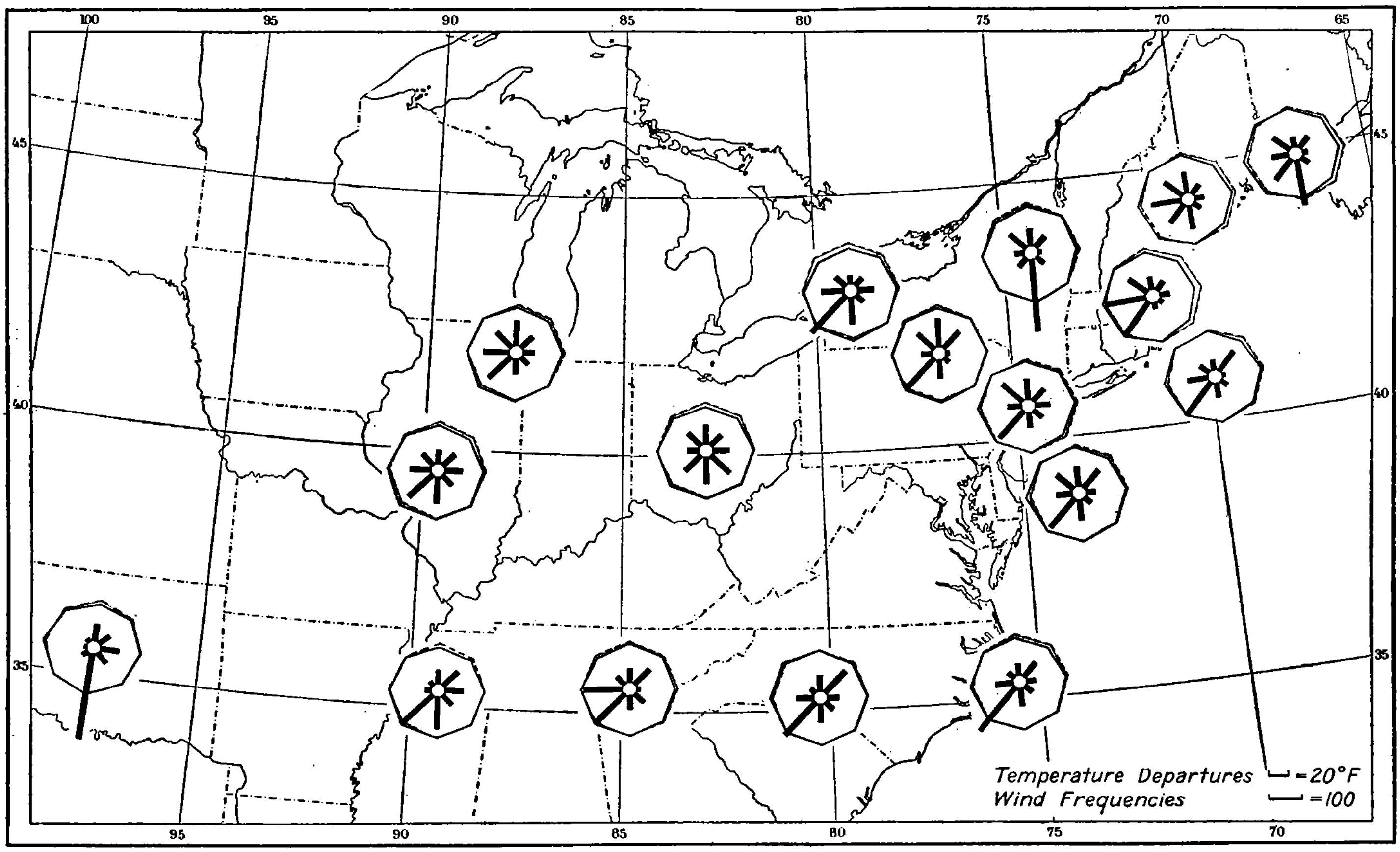

FIGURE 3.

Plus signs before the numerators of fractions for July show that in July, at every station except Atlantic City and Springfield, Ill., easterly winds bring lower temperatures than westerly winds. The fact that this is true even in the Central Plains is not attributable to the sea, but to the increased cloudiness in the northeast quadrant of a LOW. It is evident, however, that differences between southerly and northerly wind temperatures, and easterly and westerly wind temperatures, are not as great west of the Appalachians in summer as they are along the coast where, added to the lower temperature due to clouds caused both by cyclonic circulation and nearness of the sea, lower temperatures are also due to winds from the cool ocean. At Eastport, Portland, Boston, and Nantucket differences between easterly and westerly wind temperatures are very much greater than differences between northerly and southerly wind temperatures; this means that in July easterly winds bring temperatures farther below westerly wind temperatures than northerly wind temperatures are below southerly wind temperatures. If, as in January, the effect of land upon northeasterly wind temperatures and of sea upon south-westerly wind temperatures could be eliminated, the denominator might be so reduced and the numerator so increased as to indicate that sea-effects upon the temperatures are still greater compared with the effects of winds from southerly and northerly latitudes than they at first appear to be.

The relative effectiveness of winds in raising temperatures can conveniently be shown by vector diagrams, as in figures 4 and 5 for January and July, respectively. The resultants were determined by using the usual coordinate system, with the westerly minus easterly wind temperatures as one component, and the southerly minus northerly wind temperatures as the other component. On these figures all vectors point northward, showing the greater effectiveness of southerly than of northerly winds in raising temperature. Likewise, for January for all inland stations, except Chicago, which has the lake to the east, the vectors point eastward, indicating that westerly winds are more effective than easterlies in raising temperatures. The effect of winds from the ocean on temperatures along the New England coast is strikingly brought out by the *northwestward* direction of the arrows in this region.

The relative shortness of the vectors on the July chart clearly illustrates the smaller differences in temperatures accompanying north versus south winds, and east versus west winds, during the summer as compared with January. Along the New England coast in July, because the arrows point more easterly than northerly, it is

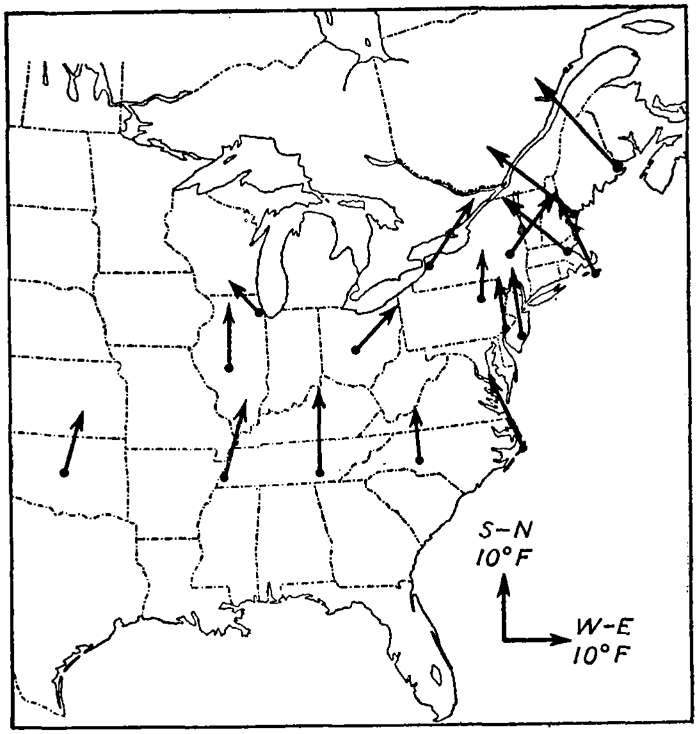

FIGURE 4.

evident that east-west winds bring greater temperature differences than north-south winds.

The magnitude of the marine effect on the average temperature of a coastal station depends on the frequency

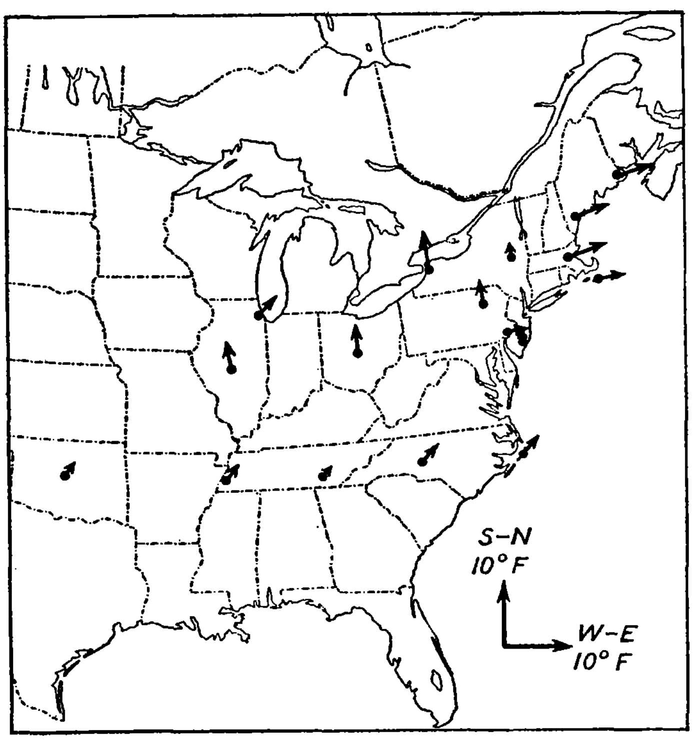

FIGURE 5.

of the winds from the sea as well as upon the temperature departures of these winds. Because of the low frequencies of sea winds along the Atlantic coast, the marine effect is correspondingly small. To obtain a conservative numerical value, the mean temperatures of days with winds from the land, or from land and sea together, may be taken to represent how much colder January might be, and how much hotter July might be, in the absence of direct pure marine influence. As a rough approximation, the average of temperatures with winds from the north, northwest, west, southwest, and south, have been computed and compared with the average for all wind directions (table 2). By such an elimination of most of the purely sea-winds and their corresponding temperatures, the temperatures at all coastal stations except Nantucket in January would be from 0°.5 to 2°.7 lower than they actually are, and average July temperatures at these coastal stations would be from 0°.6 to 1°.1 higher than they actually are. Thus Boston would have about the same average July temperature as Atlantic City now has, were the ocean taken away from the east of Boston.

TABLE 1.—*Departures of the temperatures of westerly, easterly, southerly, and northerly winds from the monthly average*

January

Station	NW., W., SW.	NE., E., SE.	SE., S., SW.	NW., N., NE.	W-E / S-N
	°F.	°F.	°F.	°F.	°F.
1. Albany	+2.8	−6.5	+1.9	−5.5	+9.3/+7.4
2. Atlantic City	+1.4	+0.3	+5.4	−4.9	+1.1/+10.3
3. Boston	−0.1	+6.0	+8.3	−2.5	−6.1/+10.8
4. Buffalo	+2.7	−5.7	+2.9	−6.4	+8.4/+9.3
5. Cape Hatteras	−0.5	+1.4	+7.1	−6.3	−1.9/+13.4
6. Charlotte	−0.2	−0.1	+4.5	−3.1	+0.1/+7.6
7. Chattanooga	+0.3	−0.5	+6.7	−5.0	+0.8/+11.7
8. Chicago	−1.6	+2.9	+3.7	+0.1	−4.5/+3.6
9. Columbus	+4.0	−3.2	+1.8	−5.1	+7.2/+6.9
10. Eastport	−2.5	+5.1	+11.7	−5.9	−7.6/+17.6
11. Memphis	−0.2	−2.9	+6.3	−5.7	+2.7/+12.0
12. Nantucket	+2.3	+5.3	+10.5	−2.2	−3.0/+12.7
13. Oklahoma City	−0.3	−1.2	+3.5	−4.6	+0.9/+8.1
14. Philadelphia	−1.5	−0.1	+4.6	−2.9	+1.4/+7.5
15. Portland	−1.1	+9.0	+11.5	−2.9	−10.1/+14.4
16. Scranton	+0.5	−1.2	+2.7	−4.0	+1.7/+6.7
17. Springfield	−0.8	−0.9	+4.9	−4.7	+0.1/+9.6

July

Station	NW., W., SW.	NE., E., SE.	SE., S., SW.	NW., N., NE.	W-E / S-N
1. Albany	−0.3	−1.1	+0.7	−1.7	+0.8/+2.4
2. Atlantic City	−1.7	−1.4	−0.1	−1.2	−0.3/+1.1
3. Boston	+1.3	−4.9	−0.8	−2.8	+6.2/+2.0
4. Buffalo	−1.7	−1.8	+1.4	−4.7	+0.1/+6.1
5. Cape Hatteras	+0.7	−1.2	+0.6	−1.9	+1.9/+2.5
6. Charlotte	+1.5	−1.0	+0.1	+0.3	+2.5/−0.2
7. Chattanooga	+0.2	−1.3	+0.2	−1.1	+1.5/+1.3
8. Chicago	+1.0	−1.7	+1.2	−1.6	+2.7/+2.8
9. Columbus	+0.3	−0.4	+1.8	−2.6	+0.7/+4.4
10. Eastport	+2.8	−3.7	−0.9	−0.9	+6.5/0.0
11. Memphis	+0.8	−0.8	+1.0	−1.9	+1.6/+2.9
12. Nantucket	+1.6	−2.0	−0.5	−1.1	+3.6/+0.6
13. Oklahoma City	+0.1	−1.2	+0.2	−2.2	+1.3/+2.4
14. Philadelphia	+1.4	−1.9	−0.5	−0.9	+3.3/+0.4
15. Portland	+1.9	−3.3	−0.6	−1.8	+5.2/+1.2
16. Scranton	0.0	−0.1	+1.5	−1.7	+0.1/+3.2
17. Springfield	+0.9	+1.9	+1.3	−2.6	−1.0/+3.9

TABLE 2.—*Elimination of purely marine winds from mean monthly temperatures*

January

Station	Average monthly temperature	Mean temperature of days with N., NW., W., SW., and S. winds	Difference
	°F.	°F.	°F.
Eastport	20°.4	17°.7	2°.7
Portland	20°.7	19°.1	1°.6
Boston	26°.7	25°.9	0°.8
Nantucket	27°.6	29°.1	−1°.5
Atlantic City	31°.7	31°.2	0°.5
Cape Hatteras	46°.3	44°.8	1°.5

July

Station	Average monthly temperature	Mean temperature of days with N., NW., W., SW., and S. winds	Difference
	°F.	°F.	°F.
Eastport	58°.7	59°.4	0°.7
Portland	66°.6	67°.4	0°.8
Boston	70°.3	71°.4	1°.1
Nantucket	67°.7	68°.6	0°.9
Atlantic City	71°.6	72°.4	0°.8
Cape Hatteras	77°.8	78°.4	0°.6